# SYNTHESIS OF VIBRATION STUDIES ON A THREE LOOP PWR INTERNALS MODEL

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## SUMMARY

The flow induced vibrations problems are of complex nature. While it is easy to measure the global effects on the structures, it is often difficult to understand the phenomena mechanisms, because the various excitation sources, cause of the structures motion, do not act separately, but in a combined way.

In the case of reactor internal structures, we have carried out a relatively complete study, based on a three loop PWR 1/8 internals model, the SAFRAN test model. Methods and specific means of calculation were associated to this experimental tool, allowing thus the understanding of the phenomena and their extrapolation to the full scale reactor. Experimental tests in air, and in still water were carried out, to determine structures frequencies, mode shapes and generalized coefficients. Flow tests were made to measure the random response of internal structures, and to get information about the fluctuating pressure field acting on the system.

The evaluation of the unperturbated pressure field and the calculation of the structures response, submitted to the flow forces, have been made by using the experimental results, the VIBRAPHONE acoustic program, and a tridimensional mechanical system taking into account local connections between shells and water interactions, i.e. AQUAMODE and TRISTANA system. The extrapolation to the prototype and the comparison with experimental results obtained on the FESSENHEIM 1 reactor internals were made. The extrapolated data are in very good agreement with the real reactor values. The main results are the following:

(1) Source aspect:

— in singularity points such as jetting areas, the pressure field spectra present the classical aspect of a turbulence one, with very small correlation lengths;

— in confined annular spaces, such as downcomer between the thermal shield and the reactor vessel, the measured pressure spectra are not simple because there is a superposition of several effects, turbulence, acoustical and hydroelastic mechanism (coupling between fluid and structures motion). So, it is difficult to assess experimentally the real turbulence field.

By using calculations and experimental results we established separately specific spectra corresponding to these three effects; the superposition of them gave us the measured pressure response. In particular, the turbulence field determined by this way, and applied on the mechanical modal basis of the structures, leads to displacements results identical to those measured effectively on the model tests.

(2) Structures response aspect:

The standard deviations of the global displacement measured and computed, on the mock-up, then extrapolated to the reactor, by the use of scaling laws, are practically the same as those directly measured during reactor tests.

In conclusion of this study, we have evaluated the main vibration source, and we have validated a method of calculation of the displacement amplitudes for this type of structures. The comparison with full scale reactor results, shows the validity and the reliability of the scaled models tests.

## 1. Introduction

The vibration behaviour of PWR internals is governed by complex phenomena the understanding of which needs a detailed analysis. The originality of the study undertaken is characterized by an approach which is both experimental and fundamental to various phenomena, and enable to initiate a methodology for analysis of PWR internals vibrations.

## 2. Work performed in this program

### 2.1 Experimental work

Several tests were carried out on the SAFRAN test loop, which consists of an hydroelastic similitude of 1/8 scale model of a 3 loop PWR (see Ref. [1]).

- Vibration tests in air and in still water, to determine the modal properties of the structures
- Flow tests, to characterize the fluctuating pressure field and to measure directly the random response of internal structures (see Ref. [2]).

Experimental results were obtained on the FESSENHEIM 1 reactor internals during cold and hot functionnal tests.

### 2.2 Calculations

The computation of the vibration properties of internal structures was made by using a tridimensionel mechanical system taking into account local connections between shells (core barrel and thermal shield) and water interactions, i.e. AQUAMODE and TRISTANA systems (see Ref. [3]), [4], [5]).

Acoustical aspect was studied with the VIBRAPHONE acoustic program (see Ref. [6]).

## 3. Main results

### 3.1 Experimental

#### 3.1.1 Source aspect (Fig. 1)

At the inlet nozzle of the vessel, the flow jet on the core barrel, produces the main important level of pressure fluctuations and the corresponding spectra of the pressure field presents the classical aspect of a turbulence one ; However, the correlation lenghts are small (about 2 diameters of the inlet nozzle).

In downcomer annular spaces, the measured pressure spectra are not simple, and present some peaks corresponding to other effects (see further).

#### 3.1.2 Structures response aspect

The internal structures respond to the flow excitation on their mode shapes ($n = 1$, $n = 2$, $n = 3$ essentially) (see Fig. 2).

### 3.2 Calculations

#### 3.2.1 Mechanical transfert function

The modelization of the internal structures was made, and the calculation with the AQUAMODE TRISTANA system gives, in still water, the resonances frequencies of the internals ; the results are in good agreement with reactor measurements values.

We found a slight difference with the model measured values, because some boundary conditions are not well scaled ; (generally, it is a difficult point on model tests). So, we have adjusted the modelization to obtain the experimental structure frequencies.

3.2.2 Acoustic transfer function

Using the VIBRAPHONE program, we calculate the acoustical transfer function of the SAFRAN loop, which is represented by a juxtaposition of monodimensional pipes.

So, wa are able to obtain the acoustic pressure response to an harmonic source situated at the inlet nozzle, in any point of the model (see Fig. 3 ). The position of the source is given by the experience.

4. Comparison of calculation and experimental results

A calculation (by AQUAMODE) of the internals response to the flow jets at the inlet nozzle, shows that the displacements level obtained are very low comparatively to the measured one. So we show that this type of excitation source is not the main cause of structure motion.

4.1 Mechanical response

In the annular spaces, we conclude that the experimental pressure field is perturbated by the acoustical effects occuring in the loop, and by the internal structures motion.

We subtract on each pressure sensor spectra, the corresponding peaks to get the local turbulence spectra.

Taking into account correlation lenghts, we calculate, by AQUAMODE, the random response of the internals, by the integration of this pressure field on the mode shapes, and using experimental results for the damping ratios of each mode.

The comparison with the experimental response is very good (see Fig. 4).

The comparison of the computed and experimental displacements obtained on the model, with those measured on the reactor are of the same order.

4.2 Source pressure aspect

The pressure fluctuation spectra in the downcomer for each point result from the superposition of three phenomena discoupled :

- the local turbulence

  Knowing the mechanical transfer function, and the experimental response, we calculate for the resonances the corresponding value of the pressure source. The comparison of these points with the experimental pressure spectra (without the acoustical and modal effects) is good. So, we justify the choice of typical source spectra, used in the response computation.

- structures motion effect

  It is computed by AQUAMODE, which gives the "pressure shapes".

- acoustic fluctuations of the system

  We know the acoustical transfer function of the system and the acoustical source associated at the jet effect on the core barrel, so we can calculate the fluctuating pressure spectra in any point of the vessel (see Fig. 5).

The spectral sum of these three effects and the comparison, for a given sensor, with experimental results lead practically at the same spectra (see Fig. 5 and 6).

We conclude that the assumption initially made on the pressure source was correct.

## 5. Conclusion

Using experimental results obtained on model and prototype, we have validated one modelization of the different hydroelastic phenomena occuring in P.W.R. internal structures.

Now, we dispose of a method allowing a correct estimation of displacement amplitudes for this type of structures.

The comparison of the model and reactor results, shows the validity and the reliability of the scaled model tests.

## References

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[4] F. JEANPIERRE, M. LIVOLANT, "Programme TRISTANA", Rapport D.E.M.T.

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[6] R.J. GIBERT, M. LIVOLANT, G. BAYLAC, "Calcul de l'amplification acoustique dans les circuits complexes : application aux vibrations des échangeurs du réacteur CHINON III", La Houille Blanche, n° 5, 1971.

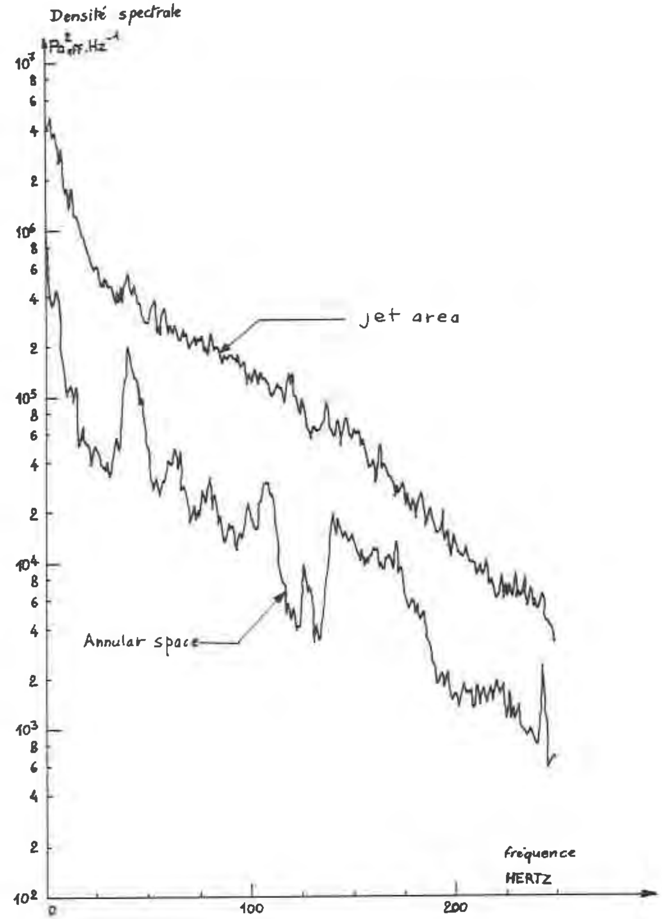


Figure 1 : Typical pressure spectra

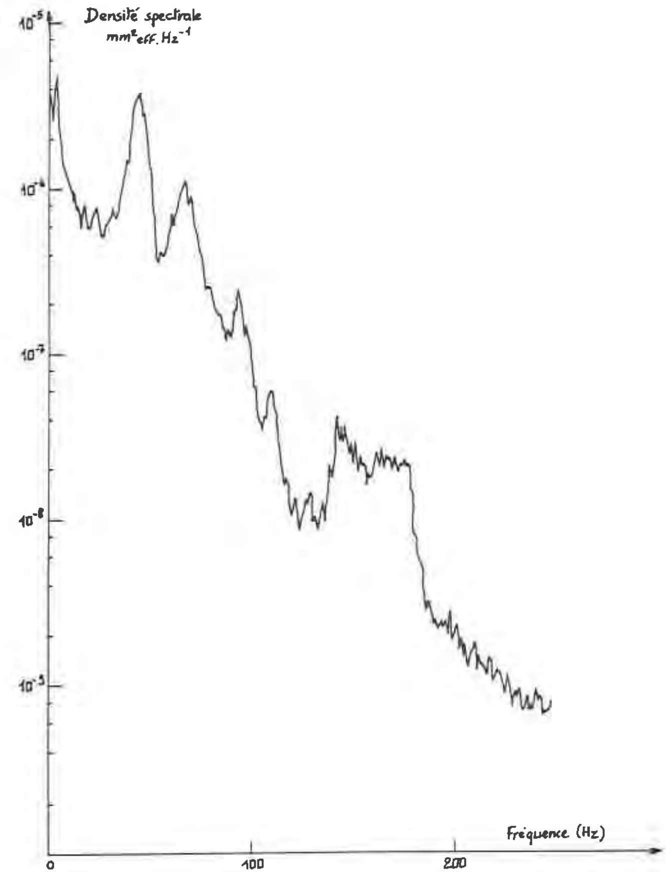


Figure 2 : Experimental P.S.D. of displacement

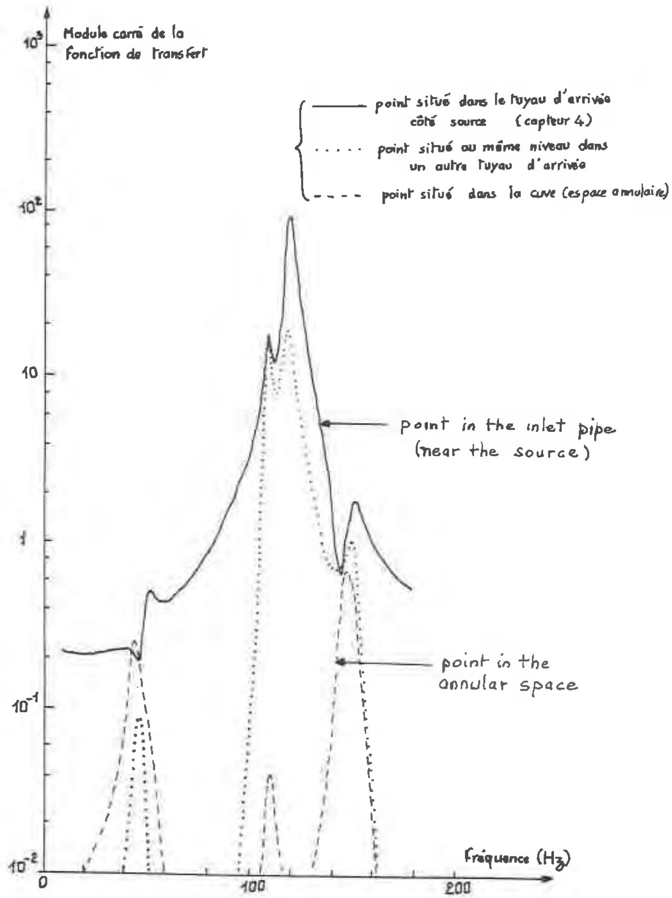


Figure 3 : Acoustical response of the loop

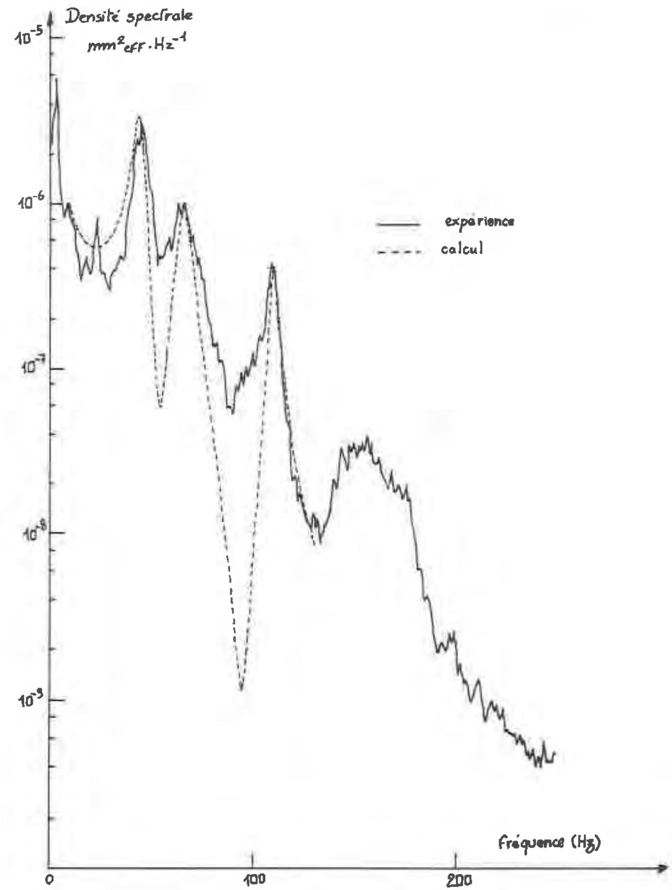


Figure 4 : Displacement spectra Comparison Experience-Calculation

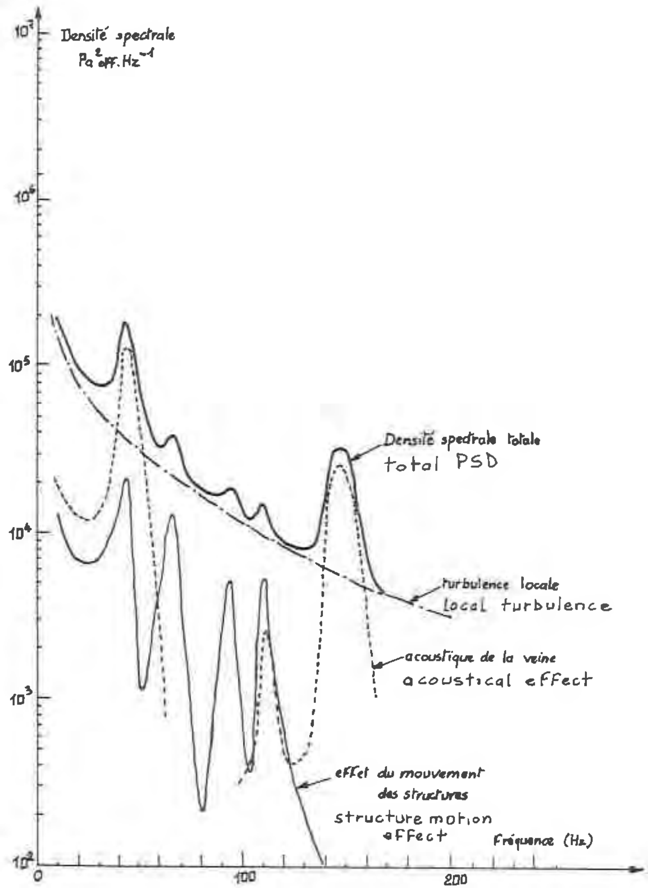


Figure 5 : Final spectra : sum of the three effects

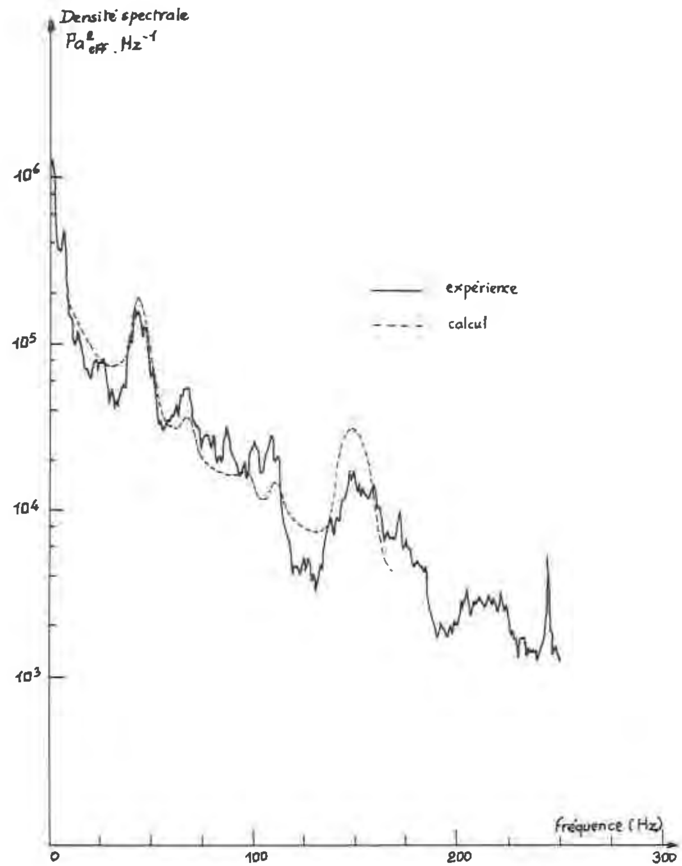


Figure 6 : Pressure spectra - Comparison Experience-Calculation